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Modeling delivery spaces schemes: is the space properly used in cities regarding delivery practices?

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Abstract

This paper discusses through modeling methods how the space is used in cities regarding urban freight transport. We will examine this question through one specific object: the loading/unloading (l/u) spaces. By comparing two fields of study (Lyon and Bordeaux in France), their actual situations and various scenarios, we will demonstrate why urban planners have to combine a large variety of solutions to improve the use of space in cities.

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Keywords: Modelling ; delivery spaces ; delivery practices ; urban planning

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1. Introduction

Quantifying spaces for freight deliveries is a fundamental stake in urban freight policies: some works showed that impertinent l/u spaces systems can have negative effects on traffic congestion and security (Aiura and Taniguchi, 2005, Delaître and Routhier, 2010). Other works investigated different solutions to reduce these negative impacts. Alho et. al (2014) present a model framework able to optimize the location and number of spaces. Unfortunately this work does not present any productions of the model because of the complexity of its calibration. Dezi et al. (2010) tackle the subject of optimizing the loading/ unloading (l/u) spaces system in a real situation with the city of Bologna. Even though not integrated in a modelling framework, this paper integrates both the temporal and spatial dimensions

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and the effects of the various configurations of l/u spaces on the urban environment, the main object of study being the loading/unloading space, its dimensions, number and location. The work presented in our paper is however not intended to discuss only these elements, but also to explore alternative solutions, to quantify their effects and to discuss the efficiency of actual l/u systems.

Until a recent period, there were no standardized methods in France to help local authorities with the problem of dimensioning l/u spaces. In 2009, the CERTU published a method to plan the needs for such objects (CERTU, 2009).

This method, suggested by the CERTU in France, translates the acceptability in terms of land use for delivery spaces for local authorities. Today this method has been adopted by many local authorities in France and is considered as a benchmark for quantifying needs for delivery spaces. We propose in this paper to compare the work of local authorities to elaborate l/u spaces systems to the methods suggested by the CERTU and to scientific methods.

The FRETURB model (Routhier and Toilier, 2007) that was calibrated thanks to the French surveys on urban goods movements (Patier and Routhier, 2009) will help us with the quantification of the needs for l/u spaces in order to absorb the freight delivery and pick-up activity. By mixing modeling and spatial analyses using GIS methods, we can refine this methodology and compare it to the reality of the field.

The CERTU method implies heavy field work. We therefore suggest the use of modeling tools, in this case, the FRETURB model, in order to generalize this method to an entire city. Indeed this model does not only measure traffic, but also the act of delivery (Gonzalez-Feliu et al., 2012).

We will compare two methods:

- Method 1, the number of movements modeled is translated to a number of delivery spaces thanks to the CERTU method. This method will be used in the paper to discuss policies on delivery spaces.
- Method 2, the number of movements is translated into consumed space by delivering vehicles, using a statistical method derived from the Freturb model results. This method will be used to discuss the real needs for l/u spaces with various shifts in practices.

Through the case study of two cities in France (Lyon and Bordeaux) we will compare the results of field work in these two cities thanks to collected and modeled data: the freight movements, the number of l/u spaces and their real uses. Thanks to this approach we will discuss the urban freight policies of cities in France, regarding the use of space.

The first method does not consider variations in delivery practices. Indeed, we will not consider the optimization measures in the modeling results of the first part of this paper. However the second method allows the discussion of shifts in delivery and pick up practices, such as reinforced control of delivery bays or delivery space booking (McLeod and Cherrett, 2011, Patier et al., 2014) or off-peak deliveries (Holguin-Veras et al., 2011). Though we won't discuss the feasibility of these measures, we will end this paper by considering their effects on different shifts in practice, urban planning and organizational measures, and their potential consequences on the use of the urban space, therefore proving that attaining sustainable freight systems cannot only be achieved through the use of space.

2. The CERTU method as a national standard

Loading/unloading spaces and their dimensions/configuration is a stake for cities. Discussing the methods that are available for urban planners and their application is fundamental for building city logistics measures. Consequently, let us first describe the methodology available in France, issued by the CERTU, which can be considered as a standard method.

Between the end of the 1990s and the beginning of the years 2000, cities in France started to tackle more seriously the problem of freight transport in urban areas. The main subject of reflection was the improvement of delivery systems in city centers such as the works done in Paris, Lyon, Bordeaux (Ambrosini et al., 1998, Ripert, 2009). This motivated a reflection in Lyon that started in 2004, about the configuration and dimension of the delivery space system in the city center. Extensive work led to the edition of a guide especially intended for urban planners to quantify the needs for l/u spaces. As this guide was only distributed in the area of Lyon, it inspired the CERTU to adapt this guide for national purposes, in order to be used in other cities in France.

The main feature of this guide is to describe a method that helps urban planners to quantify the needs for l/u spaces. The main elements that are taken into account in this method are:

- The road network of the city
- The establishments and business located in the city

Subsequently, these two elements are related to two other notions that are vital in the quantifying process:

- The notion of road segment which is useful to know where the road network is used.
- The notion of movement, which is defined as a delivery or/and a pick-up, operated by one vehicle in one establishment. Which allows us to know "how" (mainly the types of vehicles used, the number of deliveries) the road network is used for the deliveries. The French surveys on urban goods movements showed that the number of movements was mainly determined by the type of activity of an establishment and its number of employees.

The combination of these two elements determines how and where the road network is used for deliveries. This means that we can deduce the precise road occupancy generated by the vehicles in delivery or pick-up situation and consequently the need for delivery spaces.

In order to determine the number of movement on each segment, it is necessary to know exactly what kinds of establishments (their type of activity) border it. Therefore, a classification table helps with the quantification of the number of movement for each segment. The next table (inspired by the French surveys on urban goods movements) is used in the guide and summarizes for each type of activity the number of movements per week.

Table 1. Number of movements per week for each type of establishment.

Type	Movements/week
Cafés, hotels, restaurants	6.25
Bakeries	8.07
Butcher's shop, delicatessen	10.5
General grocery store	9.53
Clothes retail shops	3.23
Bookshops, stationer's shop	13.8
Other retail businesses	7.53
Furniture stores	7.50
Large stores	83.94
Wholesalers	21.67
Tertiary sector, mobile tradesmen and craftsmen	2.43
Small-scale manufacturers and small businesses	7.81

However, the temporal dimension is not taken into account in this approach. We know indeed that freight activity is uneven during the day and that peaks usually occur in the morning and in the afternoon. Moreover, the type of vehicle is not taken into account. Nevertheless, the CERTU method addresses this problem by the use of a simple "supply determination coefficient". This coefficient allows taking into account the movements' peak during the day, but also the duration of the movements. This coefficient takes the constant value of 90. Combined with the number of movements, this coefficient determines the number of l/u spaces needed to cope with the demand in terms of space for the vehicles: the number of movements found in a road segment is divided by 90 to determine the number of delivery spaces needed. This method is excessively simple to use which is an advantage for its implementation in local authorities.

The main drawback of this method is that heavy field work is necessary to characterize each establishment and the movements they generate on each road segment. Consequently, the use of modeling tools seems to be the answer to optimize the work of local authorities. We will therefore introduce the Freturb model that allows easier quantification methods.

3. The FRETURB model: explaining the modeling method

In this paper, the Freturb model plays a very important role as it is used in the two methods we will implement. The parts of the model we will use are fully explained in Routhier and Toilier, 2007, we will however expose briefly it in this part.

The main feature that will be used in the model is the generation of movements, and is common to both methods that are presented in this paper. It was proven thanks to the French surveys on urban goods movements that the most relevant characteristics that explain the number of movement for an establishment are its type of activity (a), its number of employees (o), and the nature of its premises (p) such as:

$$n_e = \varphi(a, p, o) \tag{1}$$

with n_e the number of movements per week in the establishment e. The combination of these variables allows the construction of a typology of establishments that determines for each type a number of movements. Hence, the total number of movements in a given zone z (a street, a whole district or an entire urban area), is:

$$N_z = \sum_{e \in z} n_e(a, p, o) \tag{2}$$

The results produced through this process are used in both methods, which we will now present, starting with the first method.

3.1. Combining the CERTU method to modeling results

The Freturb model determines for each establishment located in a city their number of movements. The base of this method is the use of the SIRENE[2] file which is a characterization of each establishment in a city, and is distributed by the INSEE[3]. Freturb uses this file as an input and reproduces it by adding data concerning the number of movements for each establishment. This file also gives the precise location of each establishment which allows the geolocation in the city and their location on the road network. Consequently, we can determine through the use of GIS based road network file, the affectation of an establishment to a segment of the road. Hence, the movements affected to the road network determine not the flow of vehicles, but the number of deliveries and pick-ups occurring on the network.

The use of the SIRENE is a necessity in method 1: because of geolocation constraints each establishments must have its address displayed. However, method 2 can be used in a variety of scales, including more aggregated spatial zonings, which does not necessarily needs data as accurate as the SIRENE file, therefore allowing the use of more aggregated national statistics. Indeed, it is reasonable to assume that most of the national statistical services are able to produce data concerning establishments at a municipality or an urban area level. Moreover, national statistical classification systems are similar in function to the United Nations ISIC codes[4], from which the SIRENE file is derived, allowing the generalization of the method to other countries.

The particularity of this method is that instead of having an average number of movements for each establishment (instead of the CERTU method), Freturb is able to estimate the number of movements with more precision thanks to the characterization of the number of employees for each establishment. More interestingly, the modeling approach allows the quantification of the number of movements for an entire city by statistical means, avoiding expensive field measurements or large surveys.

Once the number of movements is determined, it only takes the application of the supply determination coefficient to quantify the needs for l/u spaces.

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[2] A file describing every establishment in France, including the type of activity, number of employees, nature of the premises, location of the establishment. Every establishment in France has to be declared in this file at their creation, it is then not considered as a survey-based source.
[3] The French national institute for statistics and economic studies
[4] International Standard Industrial Classification of All Economic Activities

The main drawbacks of this method are mainly:

- the use of heavy geographical data processing (geolocation of the SIRENE file, availability of road network data, movement affectation), though local authorities usually have these sorts of data,
- the use of the supply determination coefficient, reduces the demand in space to an average, and does not take into account the type of vehicles used to operate the deliveries or the particularity of stops for each activity.

The problem for urban planners lies in both space and time repartition. Urban French surveys showed that the majority of deliveries and pick-ups are done between a two hours period (9-11 am). The peak in deliveries means that there is a higher need for delivery spaces in peak hours than there is in other periods of the day. The concentration of l/u operations during some time slots causes a problem for urban planners as they have to take into account a peak in the l/u activity. Either way urban planners are confronted to a balance problem:

- if they do not take into account the peak hours, the demand will be underestimated, generating double line deliveries,
- if they take into account the peak, most of the deliveries will be absorbed, but the consumption in space will be very important, and be perceived as a decrease of the quality of life by citizens.

We can therefore ask this question: what is the acceptable threshold for urban space use for loading/unloading operations? Statistically, delivery peaks mean massive consumptions in space to absorb freight activities. The example of Lyon shows that today, 33000 m² (0.7% of the total road network) of public space are used for l/u spaces. The regulation dictates that these spaces can also be used for car parking during the night (which optimizes the use of space during a 24 hours period), but are limited to delivery/pick-up operations between 7am and 7pm. However, in the city center, still 60% of the deliveries are operated in double line[5]. We formulate the hypothesis that the sources of this problem, among others (for example, misuse of the delivery space by other users, lack of control…), is the difficulty for local authorities to estimate the adequate number of delivery spaces in the city, and their location.

Interviews and working sessions with local stakeholders in both cities showed that delivery spaces were not dimensioned in accordance to the delivery/pick-up activities of the establishments, but rather to the demand formulated by local business owners. The real need for delivery spaces was apparently never discussed, and if space was available for l/u spaces the new configuration would be implemented. Consequently, the l/u space would often be used as a private parking for the business owners, more than a real loading/unloading space. The CERTU method was therefore never properly used in the cities we will study.

The main problem is that delivery/pickup spaces are built on public space, and that this use of space is usually confronted to other uses. We will see how urban planners did adapt the l/u spaces system to the reality of the field, by confronting the first method to the actual situation, comparing the delivery system as it should be (according to CERTU standards) and as it is now.

We will compare the results of the first method with the reality of the delivery systems in the cities of Lyon and Bordeaux. These cities are two of the largest urban areas in France (2nd for Lyon and 6th for Bordeaux), but are different in terms of density. We will for this purpose only consider the center of these two conurbations and compare them to highlight this difference in the next table.

Table 2 : Comparison of Bordeaux and Lyon according to demographical, economical and road network characteristics

	Bordeaux	Lyon
Surface in km²	49.36	47.87
Population	241287	496343
Number of employees (full time equivalent)	188423	333545

[5] Results of a survey carried out in the European project PUMAS

Population density (inhab./km²)	4888	10369
Employment density (emp./km²)	3793	6973
Length of road network (km)	714	715
Surface of the road network (km²)	4.88	4.5

The reason we only compare the center of both conurbation, is that data were only available on these spaces, and that problems with parking conditions essentially occur in the dense centers. We can observe through the previous table that Lyon is twice as dense as Bordeaux in terms of population as well as in employment. However, the total space dedicated to the road network (all uses included: pedestrians, cyclists, cars…) is equivalent in both cities. The combination of these facts means there is much more pressure on the road network in Lyon than in Bordeaux, which could mean that freight movements in obstructing situation are less acceptable. We can therefore formulate the hypothesis that Lyon as a denser city is supposed to have a more efficient delivery system.

3.2. Quantifying loading/unloading spaces

If we intuitively try to quantify delivery/pickup spaces, we can note that the statistical unit "bay" or "space" is not adapted to the needs of urban planners whose main concern is the notion of space and its uses. The number of delivery spaces is indeed a fluctuant notion that does not really take into account the space that is actually consumed by delivery spaces, as they can be of various sizes. The next graph summarizes this problem by displaying the sizes of delivery spaces in Lyon, their number and actual space consumption.

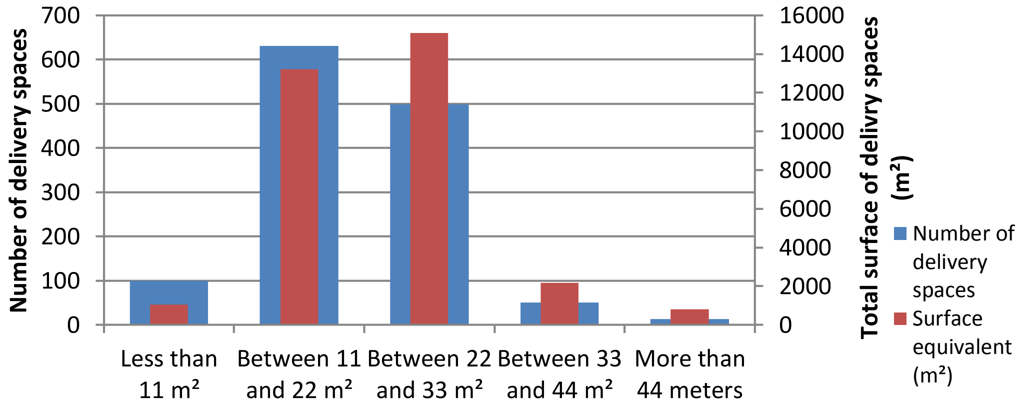

Fig. 1. Comparison of the number and total surface of the delivery spaces in the city of Lyon

Expectedly, the number of delivery space between 11 and 22 m² is higher than delivery spaces between 22 and 33 meters, but their contribution to space consumption is lower, as shown in the graph. Therefore, we will convert the number of delivery spaces into surfaces

We will now compare the results found through method 1 and the actual situation in Lyon and Bordeaux. Thanks to the application of the CERTU method altered with Freturb, we can compare the needs for delivery/pickup spaces expressed by national standards to the real situation in both cities.

It appears that in both cities, the reality meets the standards as shown in the next table.

Table 3. Comparison of the delivery spaces in Lyon and Bordeaux, through actual and data modeled with the CERTU method (method 1).

	Bordeaux	Lyon
Number of l/u spaces modeled	416	1321

Real number of l/u spaces	390	1295
Delivery space in surface equivalent (m²) – modeled	10982	34874
Delivery space in surface equivalent (m²) – real	10296	32360

These results show that cities, whatever the methods they used, are able through sensible approaches and adaptation through time, to dimension their l/u spaces systems near national standards recommendations. In fact, even if this method was first calibrated in Lyon, it was sometimes used in the hyper center of the city, but not in all areas, as for Bordeaux, there is no record of the use of this method in this place. This also suggests the level of acceptance for space dedicated to freight activity on the public road network.

We observed that the l/u space system is nowadays quite well dimensioned according to national standards. However this quantification does not reflect the real needs for l/u spaces. For example, in the center of Lyon around 60% of the deliveries are still yet operated in double line. In this case, the main reason why the l/u spaces are not used is because these spaces themselves are already used by illegally parked vehicles, which is explained by a lack of control. The second reason is also that delivery spaces are not suited for their real purpose (undersized spaces, proximity of obstacles impairing the handling operations), in this case, the problem is not due to the quantity, but rather to the quality.

In order to improve the effectiveness of the delivery space system, the main solutions that urban planners dispose of are:

- Increasing the number of delivery spaces on public road network.
- Improving the uses of delivery spaces through control (either with police or technologies) and/or configuration.
- Favoring movements time shifts (at night for example), through regulatory measures.
- Including in every new building operation spaces to internalize l/u operations.
- Optimizing the number of movements for each establishment with urban consolidation centers.

Increasing the number of l/u spaces in cities seems the easiest way to channel the movements of freight vehicles into dedicated spaces. It is however, given the rarity of space in cities, a difficult solution to apply. It is obvious that delivery/pickup spaces are not properly used in cities, especially in dense contexts as it was proven in various surveys and experiments in France and Europe (Browne et al., 2007).

Indeed, because space is rare in cities and recent policies tend to favor the uses of environmentally friendly modes of mobility (public transport, cycling…), or uses of space for leisure, more than parking and traffic, the amount of space cities can give for the deliveries is limited. Therefore, increasing the number of delivery spaces necessarily means using space for parking or other uses, but is not either necessarily enough to absorb the delivery activities or acceptable for local authorities.

Furthermore, the predominance of double line deliveries highlighted the problem of control and law enforcement, which seems to be the answer to improve the respect of regulations on freight movements when they exist, and subsequently the use of l/u spaces. Indeed, an efficient control is only possible if regulations exist and are clear. This implies training police forces and communication with the transport professionals. But it is also possible to improve the use of delivery spaces by implementing new technologies that improve controls and help regulating the use of l/u spaces (cf. FREILOT project[6]).We can therefore suggest that controlling the use the spaces can improve the use of road network drastically, without needing extra delivery spaces.

Another solution consists in altering the time profile of deliveries (through off-hour deliveries), and seems to be an acceptable solution concerning space consumption. We will not discuss the implications of night deliveries in terms of social and economic acceptability, but it seems obvious that these alternative practices can improve the use of space in cities concerning delivery activities, but also limit traffic disturbances.

[6] A European project of the seventh framework program, created to evaluate the impacts of new technologies on urban freight transport

Imposing freight space ratios in building operations is also a way to absorb l/u activities out of the public road network. This implies advanced knowledge by urban planners in terms of modelling tools, but also a certain insight in the projects that are developed on their territories. It also implies distracting space in projects which feasibility is often tightly linked to the quantity of « financially productive » space, which is reduced by less productive spaces such as l/u spaces. This depends on the power of municipalities to accept or refuse new buildings according to various standards. This solution is however not relevant for already built areas, and especially historical city centers, with small road capacities, and small technical possibilities at all to internalize deliveries and pick-ups. We will therefore not discuss the integration of freight ratios in buildings, because of its low pertinence for most of the already built and dense city areas. We will not discuss the use of urban consolidation centers either, but it would be interesting to discuss this sort of scenario in a dedicated paper.

We will now present the second method entirely based on the Freturb model, which allows us to question the different solutions previously suggested.

4. Using the Freturb model to compare actual practices and scenarios

The second method is entirely based on the computations of Freturb results, with no additional data sources. Consequently it only needs basic inputs (the SIRENE file and the zoning file, the two inputs of Freturb) to be operational, so there are no needs for heavy GIS process to caliber the model. This method also takes into account with more accuracy the duration of the movements and the type of vehicle used to perform them. Finally, we can precisely determine the peaks in terms of movements during the day, thanks to hourly profiles.

The movements in the Freturb model can be further characterized through their duration for delivering or picking up goods once the vehicle is stopped, and are also broken down into three types of vehicles (LGV and HGV, the latter being either rigid or articulated). This feature is implemented in method 2 in order to determine the turnover of the different types of vehicles for each establishment, thus quantifying the space consumed by the vehicles. The main variables that are taken into account to compute the duration of a movement are:

- The type of vehicles, which explains the weight and volume of the goods delivered or picked up.
- The type of stop.
- The number of stops in the round (if it is a round).
- The density of the zone (population and movements), which explains the efficiency of the handling operation through the availability of space.
- The type of activity delivered, which explains the type of goods and packaging.

The result of this module renders for each establishment the total duration of stops for each type of vehicle for one day.

Another feature used in the model is the characterization of the parking situation. Movements in Freturb are characterized into 4 categories related to the condition in which they take place:

- Double line.
- Authorized (in delivery space).
- Unauthorized (on the sidewalk for example).
- On private parking (the establishment has its own delivery space).

In this paper, the types of movements we are interested in are the first three, as we try to answer the question of the needs for l/u spaces on the public road network. Unauthorized and double line movements will be regrouped under the same category (as “obstructing” movements), as this type of practice provokes disturbances on the public space.

To determine the proportion of each type of stop, the model is sensitive not only to the type of activity and the size of the establishment, but also to the density of the zone it is located in (both in population and employment), in order to reflect the availability of space and the possible conflicts of uses between freight vehicles and others.

The movements of each establishment are ventilated into the four parking condition (*pc*) categories *s* in each zone *z* thanks to the following parameters:

$$pc_{s,z}\% = \psi(\delta p_z, \delta m_z) \tag{3}$$

with δp_z the density of population and δm_z the density of movements.

Of course the model was calibrated through surveys that were carried out and analyzed from the mid-1990s to the early years of 2000, moreover only in France. So it is possible that the practices described by the model might not be up to date because of new regulations, practices, etc. However, recent studies show that the relevant variables are still the same and that the results found through local surveys and Freturb modeling are very close and did not vary significantly in time (Patier and Dufour, 1999, Browne et al., 2007).

In order to quantify the space consumed by goods movements, we first need to know how many vehicles stop in an area for a given period of time. Thanks to movements-time profiles, we can quantify the total duration of stops for each half hour. These profiles were calibrated thanks to the French surveys, so we can assume they are relevant in our case study, but we can't be certain of their transferability in other countries. The next graph shows the number of movements during one day, for each type of vehicle (the perimeter is the urban area of Lyon).

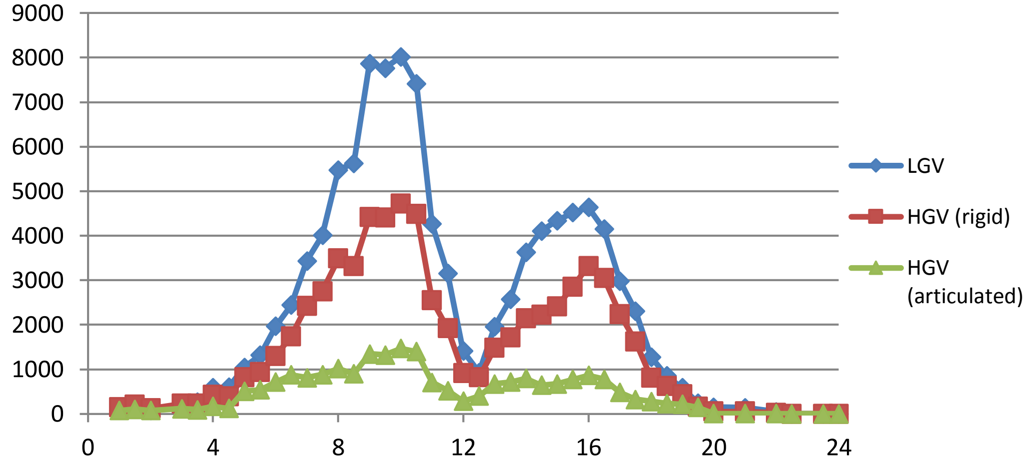

Fig. 2. Repartition of movements during the day and l/u spaces capacity (x axis is the hours of the day, y the number of movements related to the delivery capacities).

The number of vehicles per half hour is:

$$V_{v,e,t} = \frac{D_{v,t} \cdot R_{e,t}}{T} \tag{4}$$

With $D_{v,t}$ the total duration of stops for each type of vehicle *v* for a time slot *t* and *R* a matrix that gives the repartition of movements during the day per half hour time slot *t* for an establishment *e*, and *T* being a constant value in hours (T = 0.5). The result $V_{v,e,t}$ is the number of vehicles per half hour in each establishment by type of vehicle and time slot. By identifying three types of vehicles, we can deduce the space of each type of vehicle. Traditionally, the road occupancy is measured through the use of the Passenger Car Unit (PCU), we however suggest the use of spatial units (such as m² or km²) to measure the road occupancy by loading/unloading vehicles, which is more suitable for the dimensioning process for urban planners. We therefore need to convert the number of vehicles into space by applying to each type of vehicle standard surfaces *s*, that allow maneuvers, loading and unloading operations. By applying these dimensions to the number of vehicles quantified beforehand, we can then determine the space that is used by goods vehicles during the delivery/pick-up operations. The total surface of the l/u space system *S* is dimensioned according to the delivery peak *tmax*:

$$S_{tmax} = \sum_{e,v} V_{v,e,tmax} \cdot s_v \tag{5}$$

With s_v the surface of each type of vehicle *v*.

If this method is fairly precise in the temporal dimension, it does not allow the precise location of the movements on the road network, and only gives the quantity of space needed to absorb the freight activity on a large scale. Hence, the main drawback of this method is the lack of geographical precision, as we use neither road network data, nor geo-located establishments. The larger scale is however well suited to discuss long-term scenarios, which we will now do.

Before examining the results of the Freturb method (method 2), the next figure synthetizes the different processes used in both methods their purpose and articulation with the original CERTU method and the Freturb model.

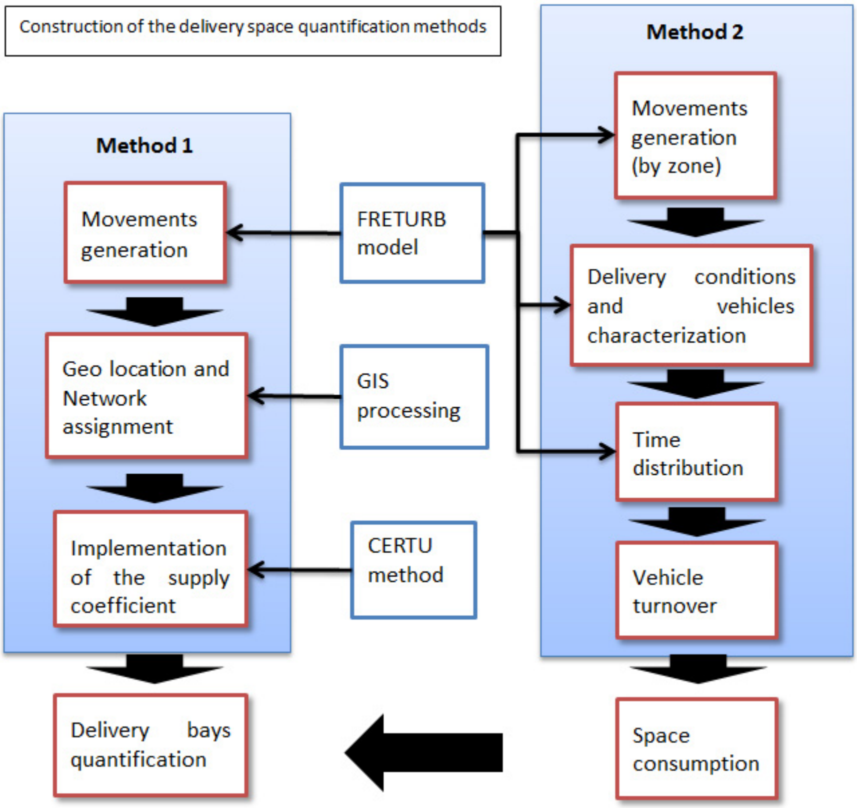

Fig. 3. Summary of the delivery space quantification methods used in this paper.

4.1. Approaching the use of space through urban planning and new practices scenarios

We will now discuss through a series of scenarios with method 2, the various effects of the different solutions that were suggested previously:

- Increase of the number of delivery spaces,
- Improvement of control and use of already existing delivery spaces,
- Off-peak deliveries/pickups.

In each of these scenarios, we will highlight the need for space during the peak hours.

The first scenario discusses the increase of l/u spaces to absorb all the movements that are operated in double-line or forbidden situation (which we will both regroup under the “obstructing” or “illegal” terminology). In this case, we try to configure the l/u spaces system according to double line deliveries only, without improving the use of the already existing system, which means that it is necessary to add delivery space to the actual delivery spaces capacity (in the graphs in dotted black lines).

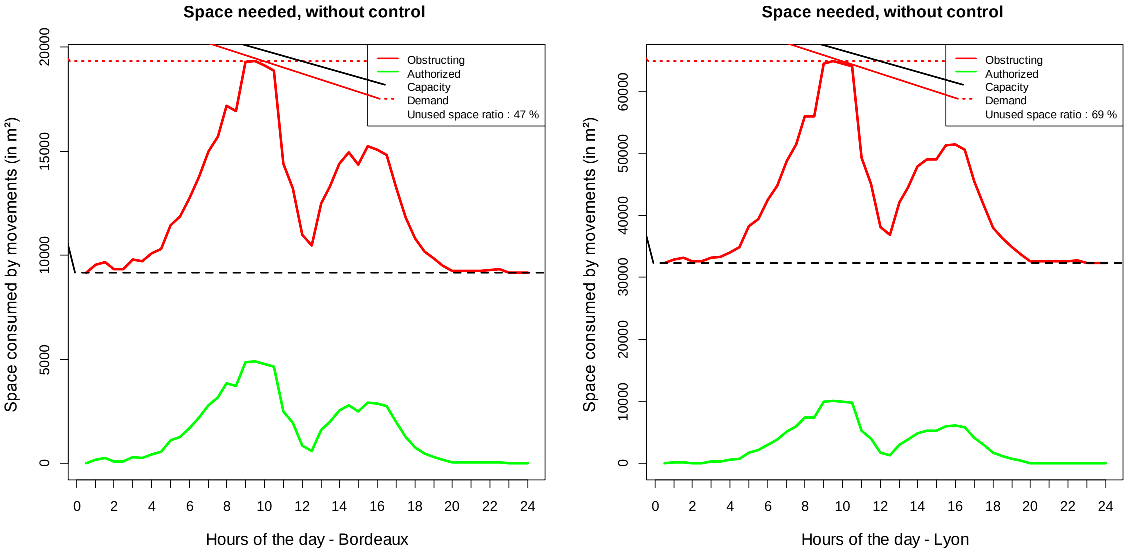

Fig. 4. Comparison of additional consumed space by double line deliveries in Bordeaux and Lyon, without improvement of the use of delivery spaces

The green line is the space used by vehicles in l/u spaces. The red line is the space used by vehicles in illegal situations. In this graph we highlight both the quantity of misused space (differential between the green and dotted black line) and the additional quantity of space used by illegally parked vehicles (which we add to the already dedicated space for l/u operations). The results aggregate the space consumed by goods movements through willingly dedicated spaces (l/u spaces capacity), and the space that is used by vehicles in double line situation. This scenario represents the actual space consumption of freight movements.

We can notice that depending on the city 47 to 69% of the loading/unloading space is not used for the freight movements (green line), which, as we mentioned earlier, implies a misuse of the space by other types of vehicles, or that transport operators don't use them : this indicator highlights the potential improvements of the delivery space uses. These results are confirmed through various surveys on urban goods movements carried out in Bordeaux, Paris, Dijon and Marseille (French surveys on urban goods movements), but also by smaller local surveys in Lyon for example (cf. PUMAS project). The results show that between half and two-third of the freight movements are operated in double line situation. This scenario implies increasing by approximately 100% the space dedicated to freight movements: for Bordeaux, going from 9000 m², to more than 19000 m², and from 33000 m² in Lyon to 65000 m² of delivery spaces.

The cost in space in centers is very high, and other uses of space in cities tend to constraint the extensions of delivery systems. Moreover, it is not guaranteed that the additional delivery spaces will be used properly, which can be considered as a waste of space. We can indeed see in the graph that there is a gap between the real capacity of the existing l/u spaces and the movements really operated in them. Therefore, before adding capacity, urban planners should work on the better use of the already existing space.

We indeed think that alternative solutions to additional l/u spaces would be to improve their use through control for example, or new technologies, such as delivery space booking (cf. European FREILOT project). In this scenario, the capacity of the misused l/u spaces is reused to absorb the obstructing movements, thus limiting the impact of stops on the road network: delivery spaces are then more intensively used.

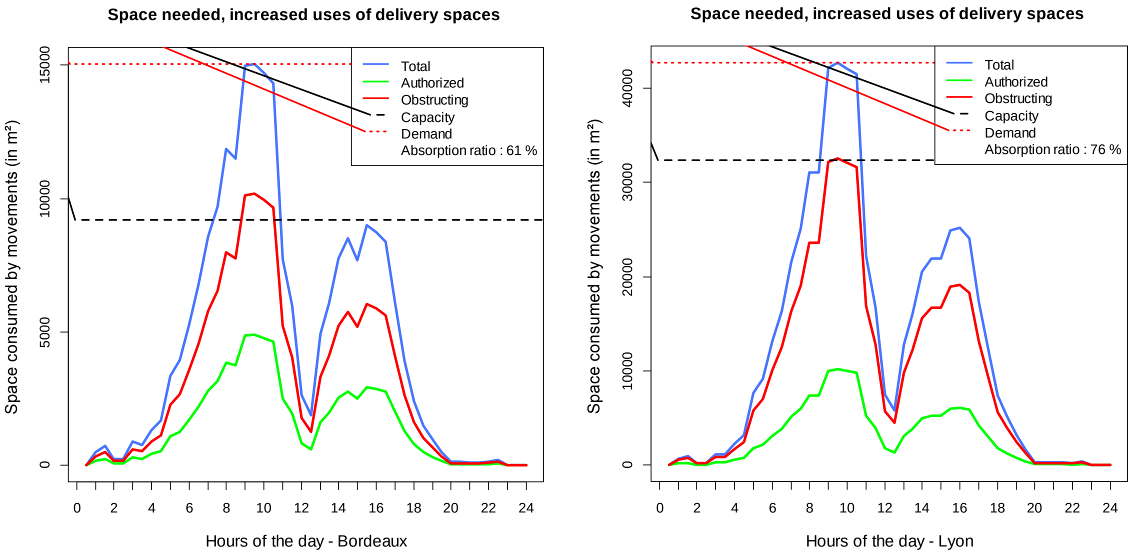

Fig. 5. Comparison consumed space by vehicle movements in Bordeaux and Lyon, with improvement of the use of delivery spaces

We can see in this scenario that the need for additional space is far lower than in the previous scenario. The space needed to absorb all of the movements in Bordeaux and Lyon drops respectively in each city from 19000 m² (in the first scenario) to 15000 m² and from 64000 m² to 42000m². On the other hand, the proportion of double line deliveries (without additional delivery spaces) drops to 37% (Bordeaux) and 22% (Lyon). We can moreover see that the l/u space system in Bordeaux is slightly under sized compared to Lyon. This also means that although the delivery spaces system in both cities correspond to national standards, it is still not enough to absorb all the freight movements, thus creating disturbance due to conflicts of use through double line parking or other obstructions.

This shows that the CERTU method suggested to quantify l/u spaces is not perfectly suited for the uses we estimated. This is essentially due to its lack of precision in the movements' estimation process, but also in the characterization of the movements into vehicles and space.

Thus, even if the already existing space was properly used, it would not be sufficient to cancel all the negative effects on road network. In the case where we improve the use of l/u spaces, increasing their number can be implemented by local authorities to an acceptable extent. Alternatively, it is possible to attain an objective of total absorption of goods movements through other means, as it is discussed in the last scenario.

This last scenario combines off-peak movements with better uses of the delivery space. Here we try to find if the existing capacity is finally enough to absorb the totality of the movements of vehicles. By off-peak movements, we imply a transfer of a certain amount of movements from the highest peak in the morning (9 to 12 am), towards earlier hours in the morning (in this case 5 to 7 am), and to the evening (from 8 to 11 pm). In this scenario we reduce the number of movements in the morning peaks by 25% and transfer it to the early morning and late evening time slots, which is an optimistic scenario given the economic structure of the cities and the applicability potential (Holguin-Veras et al. 2011). By altering the profile R_e of movements for each type of establishment, we can estimate the effect of off-peak hours on vehicles movements during the day but also the space consumed by delivery and pick-up operations.

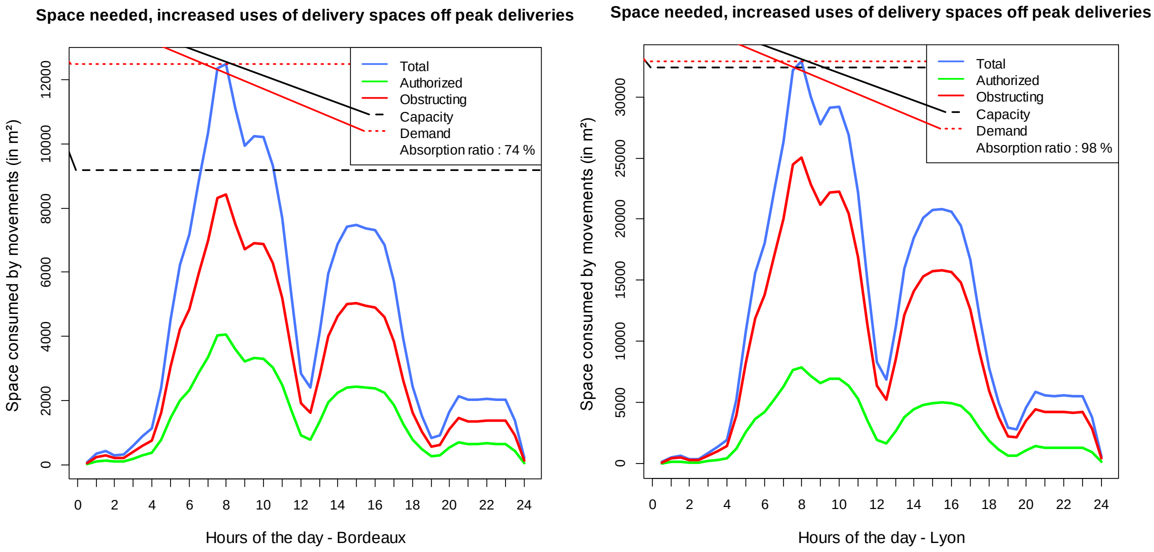

Fig. 6. Comparison consumed space by vehicle movements in Bordeaux and Lyon, with improvement of the use of delivery spaces and off-peak deliveries

In this scenario peaks still exist, but their impact is much lower than in a normal situation. In fact the obstructing road occupancy is reduced by 15%, to the point where almost every movement can be absorbed by the actual l/u space system in Lyon. The system is yet still overloaded in Bordeaux but we now need a total of 12500 m² to absorb all of the movements, instead of more than 19000 in the first scenario. In the case of Lyon, we can even imagine a situation where space is redistributed to other types of uses. Of course the results can even be better if the freight activity is leaned during the day, which could be the case in the city of Bordeaux: by further smoothing the peaks we can avoid increasing the space needed to absorb goods movements, for example between 12 am and 2 pm. The next table syntheses the different combination between scenarios in each cities.

Table 4. Combination of the various scenarios presented in this paper

City	Off-peak deliveries	Space consumed in each situation (in m² during the peak)		Actual capacity (in m²)
		Without delivery space uses improvements	With delivery space uses improvements	
Lyon	No	64955 (2598 spaces)	42722 (1709 spaces)	32383 (1295 spaces)
	Yes	57440 (2298 spaces)	32936 (1317 spaces)	
Bordeaux	No	19362 (774 spaces)	15057 (602 spaces)	9191 (390 spaces)
	Yes	17613 (704 spaces)	12492 (499 spaces)	

5. Conclusion

These series of simulations show that improvements in the freight transport system, certainly relies on dedicated space, but is also in regulatory, organizational and law enforcement solutions. The framework we established could be useful for local authorities to refine their freight policies regarding the use of space on their territory. We can see that the highest potential for improvements lies in a better use of the delivery spaces, more than in off-peak deliveries, or higher number of delivery spaces.

Moreover, the results show that in fact, if the l/u spaces system is dimensioned according to the real needs, it is mostly unused during off-peak hours, which can be interpreted as a waste of space. For example, off-hour movements imply l/u spaces that are available almost 24/24h. This leads to question of the acceptability of goods movements' disturbances vs the creation of dedicated spaces for freight operations. This issue should be addressed through further research including the value of time and space in order to determine the best possible outcome for cities.

Unfortunately we could not further discuss the feasibility and implications of the different scenarios such as off-peak deliveries and urban consolidation centers. The reason was mainly that both of these scenarios imply extensive methodology to calibrate and would not have fitted this paper. We however hope to work on these subjects in a near future.

Lastly we can note that if the two methods described in this paper both have drawbacks, mixing them together could be extremely interesting to improve the precision of the delivery spaces quantifying process, though adding complexity to the quantification process.

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